Health Council of the Netherlands

Heat stress in the workplace

Gezondheidsraad
Health Council of the Netherlands

To the Minister of Social Affairs and Employment

Subject : presentation of advisory letter *Heat stress in the workplace*
Your reference : ARBO/A&V/2007/22676
Our reference : 895/07/CB/mj/832-T
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Dear Minister,

I hereby present you with the advisory report Heat stress in the workplace. This is the first in a series of advisory reports on the occupational risks covered by the Working Conditions Act and its associated regulations.

Occupational heat stress depends not only on environmental factors such as air temperature, air humidity, wind speed or ventilation and radiant heat, but is also strongly determined by the degree of effort exerted during working activities, clothing, and individual factors. The question addressed in this report is whether at the present time new scientific insights are available, or may be expected in due course, with regard to concrete health-based and safety-based occupational exposure limits for heat stress in the workplace.

The short-term adverse effects of heat stress have been relatively well researched and described. In the 1980s, understanding of the short-term physical effects prompted the creation of health-based reference values and occupational exposure limits which have remained in use to this day. The aim of these values is the prevention of acute heat illnesses. Because there are several different causes of heat stress, a series of occupational exposure limits was developed.

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Besides these short-term physical effects, heat stress can also lead to adverse effects on mental performance, including reduced vigilance. Our study of the scientific literature on the subject suggests that such adverse mental effects appear at lower levels of heat stress than do the physical effects. The reference values employed by enforcement authorities in the Netherlands take no account of these short-term mental effects. Although a reduced level of vigilance is not a health problem in and of itself, in numerous working situations it could lead to an increased risk of mistakes and accidents.

In the Committee's judgement, current scientific insights do not give reason to revise existing health-based reference values and occupational exposure limits for heat stress with regard to its short-term physical effects. However, it does recommend to examine the possible formulation of safety-based occupational exposure limits for heat stress with regard to its effects on mental performance. The present state of research into the long-term effects of heat stress is inadequate to serve as a basis for occupational exposure limits.

The Committee has made use of the comments received in response to a public draft of this report, and also of the opinions sought from the Standing Committee on Health and Environment, a permanent board of experts drawn from within the Health Council.

Copies of this report have been sent to the Minister of Health, Welfare and Sport, and to the Minister of Housing, Spatial Planning and the Environment.

Your sincerely
(signed)
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to:

the Minister of Social Affairs and Employment

No. 2008/24E, The Hague, November 24, 2008

The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is “to advise the government and Parliament on the current level of knowledge with respect to public health issues and health (services) research...” (Section 22, Health Act).

The Health Council receives most requests for advice from the Ministers of Health, Welfare & Sport, Infrastructure & the Environment, Social Affairs & Employment, Economic Affairs, Agriculture & Innovation, and Education, Culture & Science. The Council can publish advisory reports on its own initiative. It usually does this in order to ask attention for developments or trends that are thought to be relevant to government policy.

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This report can be downloaded from www.healthcouncil.nl.

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Executive summary

The request for advice

In the present report, at the request of the Minister of Social Affairs and Employment, the Health Council of the Netherlands has investigated whether at the present time there are any new scientific insights concerning health-based and safety-based occupational exposure limits (OELs) for heat stress in the workplace, and whether any such insights can be expected in due course. This report is the first in a series of reports examining occupational risks covered by the Working Conditions Act and its associated regulations. In order to be able to answer the Minister's questions, the Committee studied scientific data on the adverse short-term and long-term effects of heat stress. In this report, the Committee makes no proposals concerning the level of an OEL.

Heat stress in the workplace

Heat stress in the workplace is not simply a question of ambient temperature. An equally important factor is the degree of effort associated with the work in question, since this can result in the production of considerable amounts of body heat. Can such body heat easily be dissipated to the immediate environment, or is this process impeded by clothing? In addition, the response to heat stress varies from one person to another. At the individual level, acclimatisation and fitness are the main factors that reduce an employee's susceptibility to heat stress.

OELs and the effects of heat stress

The Netherlands has no statutory OELs for heat stress. There is a set of reference values, however, which is used for the purpose of compliance. These are described in ISO 7243: 1989. At international level, the most widely known OELs are those that were recommended by the American National Institute for Occupational Safety and Health (NIOSH). Both the NIOSH-values and the reference values are based on the prevention of acute heat illnesses (such as heat exhaustion and heat-stroke), which involves using body core temperature as an indicator.

A survey of the scientific literature reveals that research into heat stress has mainly focused on its adverse short-term physical effects. The bulk of these studies were carried out under controlled conditions. The amount of research data relating to realistic work situations is very limited.

Results from more recent scientific research show that heat stress also causes adverse short-term mental effects. Reduced vigilance and poorer performance in terms of other mental functions were observed at environmental heat levels at which there was still no indication of adverse physical effects. The scientific literature indicates that heat stress results in an increased incidence of unsafe acts and a greater risk of accidents. In work situations, effects of this kind can endanger the health of an individual or that of others.

Conclusions and recommendations in relation to OELs

Reference values for the adverse short-term physical effects of heat stress do not need to be revised

The Committee concludes that, at the present time, there are no new scientific insights concerning the adverse short-term physical effects of heat stress. There is, therefore, no reason to revise existing health-based OELs, such as the ISO reference values.

Reference values do not take adverse short-term mental effects into account

The reasoning which underpins the reference values and OELs recommended by NIOSH takes no account of any adverse short-term mental effects of heat stress. The Committee takes the view that current scientific insights appear to offer opportunities for the establishment of safety-based OELs for heat stress.

There is insufficient data about the long-term effects of heat stress

Too few studies have been conducted on the adverse long-term physical and mental effects of heat stress. The Committee takes the view that current scientific knowledge on long-term effects is not an adequate basis for health-based or safety-based OELs.

Background to the report

Introduction

This report discusses the health risks of occupational heat stress. This theme is becoming increasingly important in Dutch society; more days of hot and tropical weather, an ageing working population, plans for raising the retirement age to 67 years, and military peace missions all mean that occupational exposure to heat stress is increasing. Heat stress is more than the result of a high ambient temperature; air humidity, wind speed or ventilation, and radiant heat all play a role. Two other important heat stress factors are body heat generated during work, and (work) clothing. The way the body reacts to heat stress is also linked to individual factors.

The request for advice

This report is in response to the request for advice submitted to the Health Council of the Netherlands on 10 July 2007 by the Minister of Social Affairs and Employment. The request, which is given in full in Annex A of this report, specified:

- periodical reports on the existence *at the moment* of new (international) scientific insights with regard to concrete health-based and / or safety-based occupational exposure limits;

- periodical reports on the expected existence *in the longer term* of new (international) scientific insights with regard to concrete health-based and / or safety-based occupational exposure limits;
- consideration of *current* scientific insights.

On 14 March 2008 the Committee on the Identification of Workplace Risks was set up to deal with this task. The Committee is composed of experts in the areas of occupational health, safety and disease. The chairman and members are listed in Annex B of this report.

At the request of the Ministry of Social Affairs and Employment, the Committee began its work with a consideration of heat stress. Subsequent reports will examine other occupational risks listed in the Dutch Working Conditions Act and its associated regulations. It may also include new occupational health risks at a later date.

The Committee's approach

The Committee first examined whether any health-based or safety-based OELs are available in the Netherlands or elsewhere. Where such OELs exist, the Committee then examined whether these are based on the scientific understanding of health or safety issues.

The Committee then carried out a systematic examination of the available scientific literature. Do current scientific insights into the adverse short-term or long-term effects of heat stress enable the setting of health-based or safety-based OELs, now or in the future? Alternatively, do new insights make it possible to revise existing OELs?

The Committee has selected publications held to be relevant to the provision of answers to the questions listed; a report of this kind does not provide a comprehensive overview of all available publications. The Committee's reports will not ordinarily recommend levels for health-based or safety-based OELs.

Once the Committee has reached consensus, a draft of its report is made public for comment from third parties. The comments received are taken into consideration in framing the final report (see Annex C).

Literature research

The literature on heat stress was collected with the help of the online databases held by PubMed and PsycINFO. Because of the large number of references to the keyword *heat*, combined search terms were employed. In PubMed these were *heat AND (health effect) AND human*, dating from 1950 to June 2008; *(heat OR thermal) AND stress AND occupational*, dating from 1985* to May 2008; and *(heat OR thermal) AND health AND work*, dating from 2002** to February 2008. In PsycINFO these were: *(heat OR thermal OR hot) AND (performance OR cognitive OR vigilance) AND (work OR occupation* OR environment*)*, dating from 1950 to September 2008.

On the basis of their title and summary, publications were selected which were concerned with the short-term and long-term effects of heat stress on health and / or with occupational exposure to heat stress. Where possible the Committee made use of reviews and of reports drawn up by national and international advisory boards and research institutes.

Chapter contents

In Chapter 1 the Committee provides an introduction to heat stress as an occupational hazard: what do the Working Conditions Act and its associated regulations have to say about heat stress, and what definitions are therein employed? What is heat stress, and when can it be said to represent a risk to health? The Committee also describes which occupational groups are exposed to heat stress. Chapter 2 gives an overview of the most familiar OELs and their underlying relation to health science. Chapter 3 presents the short-term effects of heat stress, while its long-term effects, to the extent that these have been studied, are described in Chapter 4. In Chapter 5 the Committee discusses the available scientific data and formulates three conclusions.

* Following on from NIOSH 1986.[1]
** Following on from ACGIH 2001.[2]

Chapter 1

An introduction to occupational heat stress

This chapter gives a short introduction to the subject of heat stress in the workplace. It starts with a consideration of the Working Conditions Act and its associated regulations. It goes on to look at specific definitions, the importance of a stable body core temperature, the physiological consequences of heat stress, and occupations in which workers might expect to encounter heat stress.

1.1 The Working Conditions Act on heat stress

What do the Working Conditions Act and its associated regulations have to say about heat stress?

Articles 6.1.1 and 6.1.2 of the revised Working Conditions Decree state that:[3]

1 Taking account of the nature of the working activities being carried out by employees and the physical strain imposed on them as a consequence, the workplace temperature shall occasion no adverse health effects on employees.
2 In the event that workplace temperatures or unfavourable weather conditions could nevertheless cause adverse health effects to employees, personal protective equipment is to be made available. If the personal protective equipment supplied cannot prevent employees from such adverse health effects, then the length of time that workers are exposed to these conditions shall be limited, or working periods alternated with periods of time spent in

areas whose temperature conditions fulfil the requirements of Section 1 of this Article, such that no adverse health effects are caused.

The following Policy Guideline also applies to work carried out in high temperature environments:[4]

If the nature of the work or the nature of the workplace necessitates that work is carried out at high environmental temperatures, then the climatologic circumstances must not exceed the reference values given in:

- Annex A of the ISO 7243:1989 standard, ‘Hot environments – Estimation of the heat stress on working man, based on the WBGT index (wet bulb globe temperature)’, including the correction document C1:1996, and
- Annex C of the ISO 7933:1990 standard, ‘Ergonomics of the thermal environment – Analytical determination and interpretation of thermal stress using calculation of the required sweat rate.

The Labour Inspectorate has classified extreme heat as a ‘low risk’ problem, which means that no active inspections are made of this risk; inspections are carried out only in response to worker complaints.[5]

Table 1 ISO 7243 (1989): Reference values for the WBGT index for external heat stress.[6]

Metabolism class[1]	Metabolism, M		Reference value of WBGT[2]			
	Per unit of skin area	Total (for an average skin area of 1.8 m^2)	Acclimatised person		Unacclimatised person	
	Watt/m^2	Watt	ºC		ºC	
0 (rest)	$M \leq 65$	$M \leq 117$	33		32	
1	$65 < M \leq 130$	$117 < M \leq 234$	30		29	
2	$130 < M \leq 200$	$234 < M \leq 360$	28		26	
3	$200 < M \leq 260$	$360 < M \leq 468$	No sensible air movement	Sensible air movement	No sensible air movement	Sensible air movement
			25	26	22	23
4	$M > 260$	$M > 468$	23	25	18	20

a Metabolism class: 1 = low, e.g. light manual labour performed while sitting or standing; 2 = intermediate, e.g. continuous work using hand and arm, work using arm and leg or arm and body, walking at a speed of 3.5 to 5.5 kph; 3 = high, e.g. intensive work using arm and body, carrying heavy materials, digging, planing, chopping, mowing by hand, pushing or pulling a heavily-laden cart or wheelbarrow, walking at a speed of 5.5 to 7 kph; 4 = very high, e.g. very intensive activity carried out at high speed, e.g. working with an axe, climbing stairs or a ladder, running.

b Wet bulb globe temperature’ is an index unit for environmental warmth composed of three temperature measurements: for air temperature (dry-bulb temperature), for air humidity and air speed (natural wet-bulb temperature), and for radiant temperature (black globe temperature). The WBGT is then calculated using one of the following formulae: outside in direct sunlight, $WBGT_{outside} = 0.7T_{wet} + 0.1T_{dry} + 0.2T_{black}$; inside, or outside but with no direct sunlight, $WBGT_{inside} = 0.7T_{wet} + 0.3T_{black}$.

Although a Policy Guideline has no legal status, the reference values used in ISO 7243:1989 (Table 1) are currently used in practice as the operational norms for Dutch workplace situations.[6]

The Committee notes that the Working Conditions Decree refers simply to 'temperature' while the policy rule refers to WBGT values which comprise more than air temperature alone (see the Footnote to Table 1). Moreover, ISO 7933:1990 is no longer in use and has been replaced by ISO 7933:2004. The table containing reference values for various parameters of sweat production does no longer appear in the new version, in which heat strain is predicted using a computer model.

1.2 Definitions

Four terms employed extensively in this report merit closer description in the form of a definition. These are the terms 'heat', 'extreme heat', 'heat stress' and 'heat strain'.

'Heat' is 'strong or excessive warmth, particularly with regard to air temperature'.[*,7]

'Extreme heat' is 'an air temperature above 36ºC (dry air) or a WBGT value greater than 28ºC'.[**]

'Heat stress' is 'the sum of the heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus the heat lost from the body to the environment, primarily through evaporation'.[1]

'Heat strain' is 'the bodily response to total heat stress'.[1]

* A definition of heat which uses concrete temperatures has not been found. In the Netherlands, according to the KNMI, a 'heatwave' means that the maximum temperature in De Bilt has been higher than 25ºC for at least five successive days ('summery days') and that within those five days there have been at least three days with temperatures at or above 30ºC ('tropical days').

** Taken from the 1998 Evaluation of Health and Safety Act advice request from the State Secretary for Social Affairs and Employment to the President of the Social and Economic Council of the Netherlands (SER), dated 29 October 2004.

1.3 Body warmth in equilibrium

In order to function at rest normally, the human body requires a stable body core temperature* of 36.7ºC plus or minus 0.3 ºC.[9] The hypothalamus, located in the brain, is the centre of the body's thermoregulation. A number of hormones also play a role.[1]

When the surrounding temperature rises, and / or the body produces warmth as a consequence of its own activity, the body strives to stabilise its core temperature by dissipating warmth to the surroundings. By increasing blood supply to the skin and dilating subcutaneous blood vessels the body can dissipate heat more easily, both by dry means such as radiation, conduction and convection, and by wet means in the form of sweat evaporation.

At rest, body core temperature remains stable up to an external temperature of 29.4ºC.[10] If the temperature of the surroundings rises above this level, the human body can no longer dissipate warmth to the surroundings fast enough and the body's core temperature will start to rise.

The upper limit for thermoregulation lies at a body core temperature of about 40ºC, at which point physical exhaustion ensues.[11] A 5ºC rise in body core temperature is deemed to be fatal.

1.4 Physiological changes

Heat stress depends on a variety of factors. The determining external environmental factors are air temperature, air humidity, air speed, radiant heat, and where present, precipitation. It is also important how much physical exertion the work requires; at maximum levels of exertion, the body produces twenty times as much energy as it does at rest. About 20% of this energy is turned into muscle activity; the rest appears as warmth in the body.[12] Another equally important factor is the clothing worn during work, and its attributes with regard to thermal insulation**, vapour permeability, and ventilation. Lastly, individual factors also play a role; these have to do with age, gender, body type, ethnicity, adaptation, fitness, lifestyle and medication use (e.g. diuretics, beta-blockers, antihistamines or psychiatric medicines). With regard to lifestyle, smoking,

* Body core temperature is the temperature in the trunk and brain, preferably measured *per rectum*. Other measurement methods are by mouth, in the ear, on the skin, or using an ingested sensor.[8]

** Expressed in Clo. 1 Clo = 0.155 $m^2.ºC.W^{-1}$, and is equivalent to a three-piece business suit.

drinking and drug use are the most important indicators.[1] All these factors mean that heat stress and the associated heat strain vary from person to person.

Heat strain on the body is linked with changes in physiological parameters, of which the rise in body core temperature, heart rate and sweat production have been the most extensively researched. Not all such physiological changes are unfavourable; these changes also enable the body to actively acclimatise to heat stress (see Section 1.6). It is only when the body's core temperature continues to rise that the risk of adverse health effects appears (see Chapter 3).

1.5 Workplace exposure to heat

Workplace exposure to heat can be the consequence of heat-generating sources at work, high external air temperatures, or a combination of both. In the Netherlands, exposure to heat due to certain occupational or industrial work processes occurs all year round, while heat related to climatologic circumstances occurs principally during the summer months.

Exposure to heat-generating sources occurs in companies and industries such as the steel, chemicals and food industries, in smelting plants, in the production of paper, glass, aluminium and rubber, in combined heat and power plants, bakeries, laundries, restaurant or company kitchens, saunas and swimming pools, and in tunnel building works.[13,14]

Workers whose work entails wearing insulated clothing can also encounter heat stress; these include firemen, soldiers, asbestos workers, sandblasters, tank cleaners and refrigerated area workers.

Exposure to heat resulting from high outside air temperatures will occur primarily amongst those working outside, such as in the building trade, the road construction industry, the horticultural and agricultural sectors, the army, professional sports, or inside buildings with poor air conditioning, such as schools, offices, shops, factories, warehouses and greenhouses, and in transport vehicles having no air conditioning.[13,14]

Although annual health and safety at work reports detail a large number of occupational risks, data on heat exposure are not included. What little data exists has been provided through trade unions, as a result of self-reported exposures. The Committee has been unable to find any scientific data on the number of workers exposed and on the frequency, duration and extent of exposure in Dutch workplace environments. The Labour Inspectorate has estimated that about 30,000 workers are exposed to extreme heat.[*,5]

1.6 Adaptation to heat stress

The human body can adapt to heat stress, a process known as acclimatisation. Under normal circumstances this process takes four to six days. Over this period of time heart rate and body core temperature will gradually fall while sweat production increases.

In an unacclimatised person, the first reaction to heat stress is an increased heart rate; a later reaction is sweat production. In an acclimatised person, sweat production occurs more rapid and is more copious, and the sweat contains lower electrolyte concentrations. Full acclimatisation is in place after about seven to ten days of heat stress. Acclimatisation takes place not only under the influence of environmental heat but can also be the consequence of extreme physical exertion.

When exposure to heat stress ends, the physical adaptations to heat stress gradually disappear. It was long thought that acclimatisation completely disappears three to four weeks after exposure ends,[1,15] but recent research has shown that the favourable effects of acclimatisation on heart rate and body temperature were still detectable 26 days after the most recent exposure.[16]

Elderly people and women are less able to deal with heat stress than are young men.[17,18] This is because in elderly people, blood circulation changes mean that the skin is less well irrigated and also the heart is less robust under stress. Women have lower sweat production than do men. However, age and gender exert almost no influence in well-trained and acclimatised people.

* Based on figures published by Statistics Netherlands; the results of a national employee questionnaire and Labour Inspectorate expertise.

Chapter 2

Inventory of OELs

OELs for heat stress are generally made up of a combination of environmental and physiological parameters. Overstepping these OELs usually leads to the modification of work and rest periods, that is to say, to shorter work periods and more frequent and longer breaks. A distinction is also drawn between OELs for acclimatised and unacclimatised people. Account is taken of the nature and intensity of the work activities and where necessary with the wearing of insulating clothing. The commonest OELs are described in the following section, and Section 2.2 looks at the health science underlying these OELs.

2.1 The commonest OELs

In 1969 the World Health Organisation (WHO) published a report on the health effects of heat exposure and concluded that it was 'inadvisable for the body core temperature to exceed 38ºC or for oral temperature to exceed 37.5ºC in prolonged daily exposure to heavy work and / or heat'.[15]

In 1972, the National Institute for Occupational Safety and Health (NIOSH) developed a series of OELs for acclimatised workers (*heat-stress recommended exposure limits*, REL) and for unacclimatised workers (*heat-stress recommended alert limits*, RAL).[1] The aim of these OELs is the prevention of acute heat illnesses such as heat exhaustion and heat stroke. In 1986 these OELs were revised to reflect new scientific data on working in high temperatures. The revised OELs are based on a combination of environmental heat (measured as

WBGT) and body heat generated by physical activity. They are linked to recommendations for work and rest periods per hour (Figures 1 and 2).*

The American Conference of Governmental Industrial Hygienists (ACGIH) also seeks to avoid acute heat illness and states that heat exposure should be discontinued if a number of physiological limit values are exceeded: a body core temperature exceeding 38ºC for unacclimatised workers and 38.5ºC for acclimatised workers; a heart rate above '180bpm minus age in years' for more than a few minutes; recovery heart rate higher than 120bpm, 1 minute after peak exertion; and if there are any symptoms of sudden, serious fatigue, nausea, giddiness or light-headedness.[8,19] The ACGIH uses *threshold limit values* (TLV) which accord with the OELs used by the NIOSH (Figure 3). Where necessary, a correction factor is applied to the TLV (in ºC WBGT) when subjects are wearing insulating clothing.[19] The ACGIH has also set out limits applying to the relationship between working and rest periods (Table 2).

The American Occupational Safety & Health Administration has adopted these TLVs.[14]

The International Organization for Standardization (ISO) has formulated three ISO standards which cover practically every working situation involving heat stress, namely ISO 7243, ISO 7933 and ISO 9886. ISO 7243 covers environmental monitoring and control (Table 1). ISO 7933 is used to determine the rate of heat exchange between worker and environment, and ISO 9886 is based on the biomonitoring of body core and skin temperature, heart rate, and body weight loss through perspiration.[20]

Over the last 100 years numerous indicators for heat stress have been developed.[21] The *wet bulb globe temperature* (WBGT) (see Footnote B, Table 1) has been widely accepted as the most commonly used index for environmental heat and is based on measurements of three different environmental temperatures: dry air temperature (using a dry bulb thermometer), air humidity and air speed (using a natural wet-bulb thermometer) and radiant heat (using a black globe thermometer). These three environmental temperatures can be measured separately or integrated into a composite WBGT measurement. The determination of the WBGT is described in the NIOSH, ACGIH and ISO documentation.[1,6,8]

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* The 60 min/h curve is valid for continuous work. The 45 min/h curve applies to 45 minutes of work and 15 minutes of rest per hour; 30 min/h, 30 minutes of work and 30 minutes of rest per hour; 15 min/h, 15 minutes of work and 45 minutes of rest per hour.

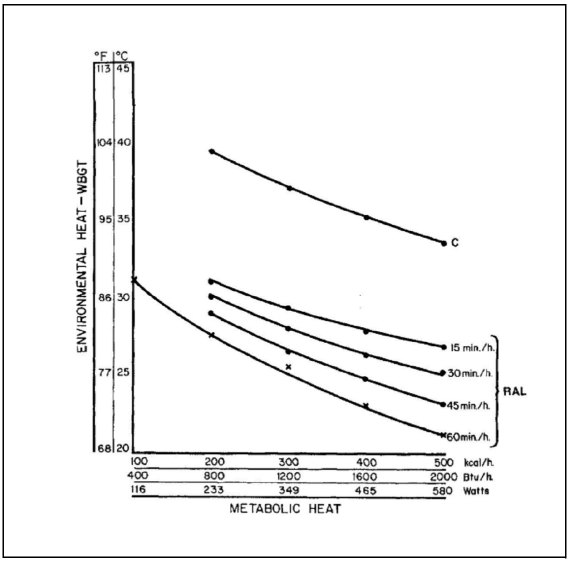

Figure 1 NIOSH recommended heat-stress alert limits (unacclimatised workers), C-curve: ceiling limit*[,1]

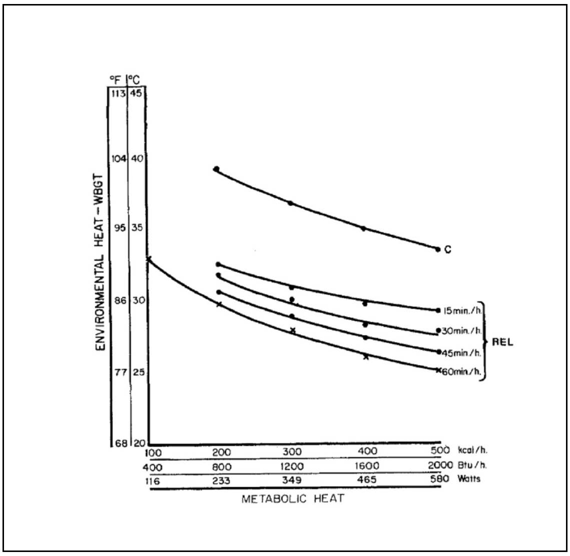

Figure 2 NIOSH recommended heat-stress exposure limits (acclimatised workers), C-curve: ceiling limit [1]

* The ceiling limit may not be exceeded.

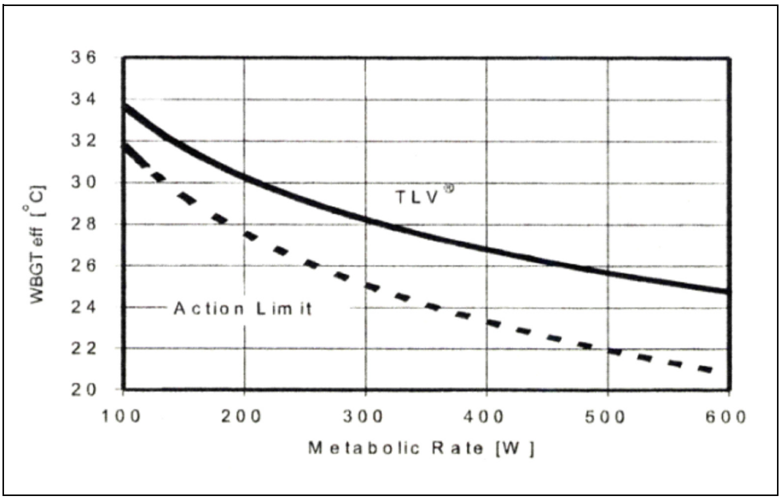

Figure 3 TLV and action limits for heat stress set by the ACGIH (WBGT in °C, corrected for clothing)[19]

Table 2 TLV and action limits for heat stress set by the ACGIH (WBGT values rounded to 0.5°C)[19]

Allocation of work in a cycle of work and recovery	TLV (acclimatised)				action limit (unacclimatised)			
	light	moderate	heavy	very heavy	light	moderate	heavy	very heavy
100% work	31.0	28.0			28.0	25.0		
75% work	31.0	29.0	27.5		28.5	26.0	24.0	
50% work	32.0	30.0	29.0	28.0	29.5	27.0	25.5	24.5
25% work	32.5	31.5	30.5	30.0	30.0	29.0	28.0	27.0

2.2 The underlying health science

The OELs set in the NIOSH, ACGIH and ISO standards are intended to prevent the body core temperature from rising above 38ºC and causing acute heat exhaustion or heat stroke.

The WHO based its conclusions on body core temperature principally on the research carried out by Lind in 1963 under laboratory conditions.[22,23] Data on real-world working situations was not available at that time.

Using three male test subjects, Lind established upper limits for the ambient temperature at different levels of short-term physical exertion: 30.2ºC (CET*) for 180 kcal/hour, 27.4ºC for 300 kcal/hour and 26.9ºC for 420 kcal/hour.[22] Below

* 'Corrected effective temperature', the precursor to the WBGT as an index measure of environmental heat, which comprises measurements of air temperature, air humidity, air speed, and radiant heat.

these ambient temperatures he found no change in rectal temperature. In a follow-up experiment using two test subjects he found that when a physical exertion of 300 kcal/hour was sustained for eight hours this had no effect on rectal temperature, heart rate and sweat loss, provided the ambient temperature was below 27.4ºC (CET).[23]

The NIOSH (1986) based its recommended OELs on risk calculations for the consequences of heat stress on body core temperature.[1] The basis for these calculations is the research carried out by Wyndham and Heyns in 1973.[24] Using epidemiological data from South African mines, the researchers concluded that the risk of heat stroke rises quickly above 32ºC (ET*) while the risk of non-fatal heat stroke becomes negligible below 27ºC. On the basis of laboratory studies, the researchers also estimated the likelihood of the body core temperature rising to a damaging level of 42ºC after four hours of various levels of physical exertion. Using this data, the NIOSH calculated the likelihood that a body core temperature of 40ºC would be reached. At an effective temperature (ET) of 34.6ºC the chance is one per million, at 35.3ºC it is one per ten thousand, at 35.8ºC it is one per hundred and at 36.6ºC it is one in three.[1]

* 'Effective temperature', the precursor of the CET as an index measure of environmental heat, which comprises measurements of air temperature, air humidity and air speed.

Chapter 3

The short-term effects of heat stress

Most of the scientific literature on the short-term effects of heat stress concerns studies in which physiological measurements are made under controlled conditions. These studies are directed towards the acute effects of heat stress during intermediate to heavy physical exertion amongst specific groups such as sportsmen, soldiers or firemen. A publication by Hancock *et al* provides a historical review of the scientific research into heat stress.[25]

The consequences of heat stress in actual workplace situations have been little investigated. The studies that do exist are concerned with workplaces in warm climates such as Australia and Asia, or describe exceptional working environments such as mining. The quality and usefulness of these practical studies is sometimes uncertain; some examine only a small number of subjects, while others give no more than summary descriptions of the study and its outcomes.

In this chapter the Committee reviews the adverse short-term health effects of heat stress found in the literature, divided into effects on physical function, effects on mental function, and effects on mortality and fertility. Chapter 4 will look at the long-term effects.

3.1 Effects on physical function

3.1.1 Heat illness in general

The most familiar short-term effect of heat stress on physical function is the appearance of heat illnesses, which can take more or less serious forms. These effects are caused when the body can no longer dissipate enough heat to the surroundings to prevent the body core temperature from rising. Heat illnesses can be manifested as:[1,26]

- Skin ailments in the form of prickly itching and papules, caused by the clogging of sweat gland drainage channels, usually underneath clothing;
- heat cramp in the muscles, caused by a disturbance in the body's salt balance (either too much or too little) through sweating, and heat oedema caused by subcutaneous fluid retention
- Heat syncope caused by an insufficient blood supply to the brain, resulting in fainting, headache, nausea and diarrhoea
- Heat exhaustion caused by dehydration, whose symptoms include rapid heart rate, a raised body core temperature of 38ºC to 39ºC, weakness and poor concentration
- Heat stroke, if the body core temperature exceeds 40.5ºC, accompanied by dry, red skin, cramps, convulsions, loss of consciousness, and damage to numerous tissues and organs. Two forms of heat stroke may be distinguished, the classic and the exertion-related. A heat stroke is a medical emergency.

The effects described above may also appear simultaneously.

If the body temperature is not quickly lowered by cooling and fluid ingestion, heat exhaustion can become a heat stroke. About 20% of those who have had a heat stroke suffer lasting damage to vital organs such as the heart, liver, kidneys or nervous system.[26] The ACGIH document provides a review of the literature on this subject.[2]

Some authorities, such as the NIOSH, include heat fatigue in this list of heat illnesses. This fatigue is associated with a temporary impairment of sensory motor and mental function, which increases the risk of accidents. This effect is usually the consequence of insufficient acclimatisation.

The Committee was able to find an informative publication from the US on the occurrence of occupational heat illness.[27] In the state of Washington between 1995 and 2006, 480 workers received compensation related to heat illness (out of a total of 1.56 million claims). The incidence of the claims was highest during the summer months. Taken over the entire period, most claims arose from within the building industry and the public sector (each yielding 12 per 100,000 FTE)*, and from agriculture, forestry, fishing and hunting (5 per 100,000). The highest annual mean numbers of claims were 81 per 100,000 FTE in fire fighting, 59 per 100,000 in the roof construction industry, and 45 per 100,000 in the road building and bridge building industries.

3.1.2 *Physiological effects in specific work situations*

Since the WHO and NIOSH reports were published more research into workplace conditions has been carried out, although high-quality, large-scale epidemiological studies have yet to be performed. The available research has been directed primarily towards the question of what happens to body core temperature and other physiological parameters when people have to deal with heat stress at work. To the not infrequent surprise of the researchers, in many working situations there appeared to be no direct relationship between measured heat stress and body core temperature. It was also found that a high body core temperature could be present in workers showing no objective symptoms of heat illnesses. Although subjective experiences of heat stress were reported amongst workers at a steel factory.[28]

Another research finding was a large variation in the physiological parameters being measured, not only between individuals, but also in the same person at different times of day. Besides the existence of a circadian rhythm in, for instance, body core temperature, researchers have identified two causes: acclimatisation and autoregulation. The latter is a behavioural adaptation in which a person reduces their own exertion levels for a period of time. Research into mining conditions, for instance, showed that heat exhaustion and heat stroke were relatively rare occurrences.[29]

Recent research into the acute effects of heat stress on one or more physiological parameters in different occupational situations is summarised in Tables 3 and 4 in Annex D.

3.2 Effects on mental performance

The scientific literature is devoting increasing attention to the effects of heat stress on mental performance – that is to say, attention, perception, thought, memory and psychomotor functions.[30] As environmental temperatures rise,

* FTE, Full Time Equivalent, equal to 2000 hours of work per year.

physiological changes are accompanied by effects such as reduced vigilance, fatigue, and the impairment of cognitive functions. In recent literature researchers have examined which mental functions are influenced, to what degree this occurs, and at what levels of heat stress.

Assuming the hypothetical model of an inverted U-shape (Figure 4) describing the relationship between stress level on the one hand (horizontal axis) and cognitive changes on the other (vertical axis), heat stress should have a negligible effect until a threshold level is reached, at which point there would be a phase of rapid decline.[10] The central question in this research is the actual threshold level for effects on mental performance, and whether this level is in line with those for heat storage in the body and changes in physiological parameters.

3.2.1 *Accidents*

In the 1970s researchers had already described how, for workers at two different metal companies, the number of perceived unsafe actions was lowest at temperatures between 17ºC and 23ºC WBGT. The perceptions and registrations were performed by independent observers. As the ambient temperature rose, the number of unsafe actions grew.[31]

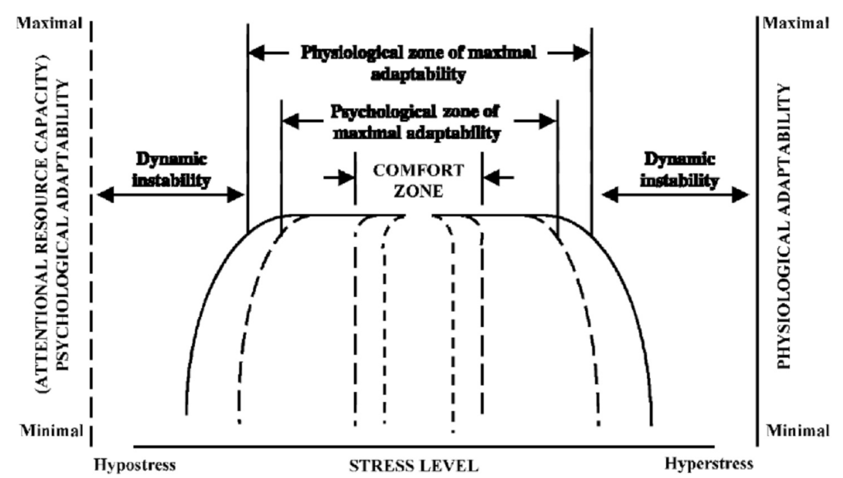

Figure 4 Theoretical model for maximum adaptation to heat stress[10]

In a study of hospital admissions in Tuscany between 1998 and 2003, other researchers found that the risk of an occupational injury was greatest when the average daytime temperature was between 24.8ºC and 27.5ºC.[32]

3.2.2 Vigilance

Research into about 500 mistakes made by Israeli helicopter pilots revealed a relationship between the likelihood of making a mistake and rising ambient temperatures.[33] There was a significantly lower risk at temperatures between 25ºC and 29ºC. The odds ratio (OR) was 0.6 with a 95% confidence interval (CI) of 0.5 to 0.8. Between 30ºC and 34ºC, the risk of a mistake was significantly raised (OR 1.6; 95% CI 1.3 to 2.0). At temperatures above 35ºC the risk rose even further (OR 6.2; 95% CI 2.1-21.8).

Vigilance was researched in a group of 83 car drivers at temperatures of 21ºC and 27ºC.[34] During a car journey of at least an hour, the test subjects were asked to react to more than 20 different signals. At a temperature of 27ºC, 50% of the signals were missed and reaction times were 22% longer compared to the results at 21ºC.The differences were statistically significant for both effects. The effect on vigilance was particularly apparent during the second half hour of the experiment and at speeds of less than 60 kph. This difference in vigilance can lead to impaired driving performance and therefore to lowered road safety. In another study of 50 test subjects, drivers showed 3% more erratic steering at an ambient temperature of 35ºC than they did at 20ºC.[35]

Eight Norwegian pilots were exposed to three different climates in a climate chamber for a period of three hours: 0ºC with 80% air humidity, 23ºC with 63% humidity, and 40ºC with 19% humidity.[36] At 40ºC they made significantly more errors in a vigilance test, and the researchers found a dose-effect relationship with a rise in body core temperature.

In the study of steelworkers mentioned earlier, the high-exposed men had reaction times which were an average of 30 milliseconds longer than those of the low-exposed group.[28]

3.2.3 Distinctions between different mental functions

In a review of about 160 studies, Ramsey concludes that visual motor function deteriorates at environmental temperatures between 30ºC and 33ºC WBGT.[37]

Hancock and Vasmatzidis researched into the fact that mental functions are influenced in differing degrees by the same heat stress.[10] They came to the conclusion that vigilance was the first function to diminish, namely when there was a rise in body core temperature of 0.055ºC per hour of exposure. Carrying out dual tasks, following a moving target on a computer (tracking), and performing simple mental tasks were all less susceptible to heat stress than was vigilance. However, all the mental functions investigated were more susceptible than were the physiological parameters, which were influenced only when body core temperature rose by 1.67ºC per hour of exposure. The same researchers discovered that a higher, 70% air humidity had an additional negative effect.[38]

Two recent meta-analyses have brought further refinement to scientific understanding of the consequences of thermal stress on mental performance.[25,39]

On the basis of the results of 22 studies, Pilcher et al. concluded that exposure to temperatures above 32.2ºC WBGT resulted in a 15% decline in mental functions.[39] At lower temperatures, between 26.7ºC and 32.2ºC WBGT, these functions were reduced by 7.5%. At temperatures between 21.1ºC and 26.6ºC WBGT the researchers detected no effects. Tasks associated with attention and perception appeared to be the most susceptible to heat stress.

A meta-analysis carried out by Hancock et al., which was based on 57 studies, confirmed this result.[25] Under thermal stress, mental performance fell by about 11%. Heat stress had the greatest adverse effect on perception-based tasks, followed by psychomotor performance and finally by cognitive performance. For all three categories, high temperatures reduced the precision with which the tasks were carried out. In perception-based activities, subjects also showed slower reaction times, particularly at temperatures above 29.4ºC. The Committee notes that both meta-analyses included both high-temperature and low-temperature effects in the first instance, thereafter followed by a subdivision into the effects of heat and cold.

The degree to which the short-term effects of heat stress on mental performance were also the consequence of dehydration cannot be determined from the available research. Other studies have described how sweat loss amounting to 2% of body weight had adverse effects on mental performance.[59,60]

3.3 Effects on mortality

Much has been published on the effects of heat-waves and their relationship with mortality in the general population, particularly after the heat-wave of 2003 in Europe and the extra deaths that ensued, especially amongst those aged 65 or more. The Committee limits itself here to mentioning two studies that concerned the Dutch climate.

Kunst et al. studied the relationship between daily temperatures in the period 1979-1987 and the daily number of deaths.[40] They found a V-shaped relationship in which an average temperature of 16.5ºC was associated with the lowest mortality rate. As the average temperature rose, so did mortality, by 1.7% per ºC temperature rise per day. Respiratory disorders were responsible for 28% of these deaths and cardiovascular disorders for 26%. To the researchers' surprise, a raised humidity reduced the rise in mortality.

These results were confirmed in a follow-up study covering the period of 1979 to 1997.[41] The V-shaped curve with an optimum temperature of 16.5ºC was found for overall mortality, for mortality resulting from cardiovascular and respiratory disorders, and for people aged 65 and over. During the heat-waves 40 more people died per day than usual. Deaths from respiratory disorders, in particular, rose by 120%. The researchers were unable to distinguish whether these were 'extra' deaths, or whether people in poor health died earlier as a result of the heat-wave (the so-called 'harvest effect'). In a recent report, the researchers concluded that both effects were probably at work.[42] In the group that was less than 65 years of age, heat exposure had a negligible effect on the number of deaths.

The Committee has found no comparable research into work situations. Although the working population is seen as being less susceptible to heat stress than is the general population, the Committee cannot exclude the possibility of an effect of heat stress on mortality amongst older workers and workers suffering from respiratory, heart or circulatory disorders.

3.4 Effects on fertility

In males, exposure to heat can lead to a decline in fertility through a reduced sperm count.[43,44] Normal spermatogenesis requires scrotal temperature to be 2ºC to 4ºC lower than body temperature. If scrotal temperature is higher than about 36-37ºC, fertility is reduced and the number of abnormal spermatozoa rises. Research into mice has shown that if the testes are warmed locally to 42ºC no spermatozoa are produced at all.[45]

Thonneau has published a review of about ten studies in which the effects on male fertility appeared to be linked to exposure to heat at the workplace.[46] Negative effects on sperm parameters and conception times for partners have been described for chauffeurs and taxi drivers, ceramic industry workers, welders, metalworkers and bakers. However, the environmental or body temperatures at which these effects appear cannot be derived from these studies. Heat exposure was reported by the subjects themselves, or assessed on the basis of work descriptions.

The consequences of heat exposure to female fertility have been the subject of very little research. In a Danish study of couples being treated for fertility problems, it appeared that occupational exposure to heat for either partner delayed conception.[47] Data on this exposure was obtained through self-reporting and was qualitative only; a recent Health Council report has called the quality of this study into question.[48]

3.5 Conclusions on adverse short-term effects

The most familiar short-term physical effects of heat stress are heat illnesses, of which heat exhaustion and heat stroke are the most serious forms. A rise in body core temperature serves as an indicator for the appearance of such heat illnesses.

In recently studied occupational situations, heat stress led to changes in physiological parameters such as body core temperature, heart rate, sweat loss, electrolyte concentrations in sweat, and hormone concentrations in urine. In some workers, body core temperature rose to above 38ºC.

Research has also shown that heat stress can lead to more accidents, mistakes, and adverse effects on mental performance. Of these mental functions, vigilance is the most susceptible to heat stress. Adverse mental effects appear to arise at heat stress levels below those associated with adverse physical effects.

For a number of professional groups, such as drivers, ceramic industry workers, bakers, metalworkers and welders, heat exposure has been linked to reduced fertility in males, but the environmental or body temperatures required to produce this effect cannot be derived from the available data. Very little research has been devoted to the possible consequences of heat exposure for female fertility.

In the general population, a rise in the outside air temperature causes a rise in the number of deaths per day amongst those aged 65 or older. These deaths can be attributed primarily to respiratory, heart and circulatory disorders.

Chapter 4

The long-term effects of heat stress

The Committee has been able to find only a limited amount of scientific literature on the long-term effects of heat stress. Published studies have been concerned only with the physical effects, the effects on the unborn child, and on the risk of cancer. These three effects are described in the following sections.

4.1 Effects on physical function

A prospective cohort study of the period between 1982 and 2000, of 218 employees of a Norwegian metalworking company, researched into the consequences of heat stress on blood pressure and heart rate.[49] Of the group under research, 25 male oven workers were exposed to heat. Despite the fact that the research was directed towards the effects of heat stress, no temperatures were recorded. Exposed and unexposed workers showed no differences with regard to blood pressure or heart rate. At the end of the period under study, total mortality in the cohort was significantly higher that for males in the general Norwegian population.

Two other studies examined the consequences to the kidneys of working under hot conditions. In a cross-sectional retrospective study of Brazilian metalworkers, 103 out of 1,289 men whose work exposed them to temperatures of 45ºC or more suffered from kidney stones.[50] Of 9,037 men who worked at room temperature, 78 had kidney stones. Heat-exposed workers also showed diminished kidney function and urine volume.

In another study of Italian male machine operators in the glass production industry, kidney stones were found in 20 out of 236 heat-exposed workers.[51] In the control group 4 out of 165 men had kidney stones. Kidney function was assessed in 21 men from the heat-exposed group and 21 men from the control group. In the heat-exposed group, dehydration had given their urine a higher uric acid concentration and a lower pH.

4.2 Effects on the unborn child

A number of studies have examined whether heat exposure during pregnancy has an effect on the unborn child.

A cohort study of 12,150 Scottish children born between 1950 and 1956 investigated the influence of outside air temperature during their mothers' pregnancy.[52] Exposure to higher temperatures during the first trimester led to a significantly lower birth weight. The researchers developed an analytical model and arrived at a reduction of 5.4 g in birth weight (95% CI 2.9 -7.9) for every 1ºC rise in temperature. When exposure to higher temperatures took place during the third trimester, however, the birth weight rose, by 1.3 g per 1ºC (95% CI 0.5-2.1).

In a patient/control study of 502 children having a congenital cardiovascular defect and 1066 control group children in the state of New York, no relationship was found with exposure to environmental temperatures above 37.8ºC (OR 1.1; 95% CI 0.6-2.2).[53] Nor was there any effect if the mother had taken hot baths or had visited a sauna. The Committee notes here that in this study only 2.7% of the women had been exposed to heat and that this exposure data was reported by the subjects themselves.

In a 2003 review, Edwards et al. state that fever during pregnancy can cause neural tube defects in the foetus if the pregnant mother's body core temperature has been 38.9ºC or more for at least 24 hours.[47,54]

4.3 Risk of cancer

Direct exposure to ultraviolet radiation raises the risk of contracting a variety of forms of skin cancer.[55] From recent research appears that simultaneous exposure to a high environmental temperature has a small additional effect.[56] An analysis of American incidence data on carcinomas in ten different regions revealed that the incidence of squamous-cell carcinomas rose by an average of 5.5% and that of basal-cell carcinomas by an average of 2.9% for every °C rise in environmental temperature. By comparison, 80% of the variance in incidence is determined by the cumulative yearly dose of UV radiation.

A study of 282 patients and 282 controls of Chinese descent living in Malaysia showed that the prevalence of nasopharyngeal carcinoma was associated with exposure to ‘industrial heat’; the odds ratio being 2.21 (95% CI 1.12-4.33, after correction for smoking).[57] The Committee notes that the subjects in this study had also been exposed to various substances (e.g. wood dust, metal, formaldehyde), and that the exposure data was derived from self-reports and was not quantified. No links were found with any of the exposures except for wood dust. With these comments in mind, the Committee is of the opinion that with regard to the outcomes for heat stress the results of this study are difficult to interpret.

4.4 Conclusions on adverse long-term effects

The long-term effects of heat stress have been the subject of very little study. With regard to physiological effects, a Norwegian cohort study found no differences in heart rate and blood pressure between heat-exposed metalworkers and their unexposed colleagues. However, two other studies found that heat exposure was linked to the presence of kidney stones and impaired kidney function.

With regard to the influence of heat stress on the unborn child, effects were found in a number of studies. A cohort study of Scottish children linked their pregnant mothers’ exposure to high outside temperatures during the first trimester with a lower birth weight. If this exposure took place in the third trimester, however, the birth weight was raised. A study of congenital cardiovascular defects in children in the state of New York found no relationship with the mother’s exposure to heat during the pregnancy.

The risk of developing cancer after heat exposure has also been given little research attention. In a patient/control study carried out in Malaysia, a link was found between the prevalence of nasopharyngeal carcinoma and occupational exposure to ‘industrial heat’. Because of the absence of quantitative data on this heat and the combined exposure to toxic substances the Committee is of the opinion that the results of this research are difficult to interpret.

Finally, research has shown that a high environmental temperature slightly increases the risk of contracting skin cancer from ultraviolet radiation.

Chapter 5

Review and conclusions

The Minister of Social Affairs and Employment requested the Health Council to report on whether *at the present time* or *in due course* new (international) scientific insights exist or might be expected to arise with regard to concrete health-based and safety-based OELs for occupational heat stress. The present report provides answers to these questions.

In its deliberations the Committee has adhered to the principle that, taking account of the nature of the work activities and the physical exertion they demand, workplace temperatures should not be permitted to damage workers' health. In answering the minister's questions the Committee studied data published in the scientific literature on the adverse health effects of heat stress. These adverse effects concern short-term physical and mental effects, long-term physical effects, the risk of contracting cancer, effects on fertility, and effects on the development of the unborn child.

The Committee has omitted from consideration those workplace situations in which the ambient temperature is experienced as merely uncomfortable.

5.1 Scientific insights into existing OELs

The reference values given by ISO 7243:1989 and the recommended OELs such as those given by the National Institute for Occupational Safety and Health (NIOSH) are based on the prevention of such adverse short-term physical effects as heat exhaustion and heat stroke. The body core temperature is the most important indicator for the development of these adverse health effects. The existing OELs ensure that the body core temperature does not rise above 38ºC. However, individual OELs are strongly dependent on the degree of physical exertion and whether or not a worker is acclimatised to heat stress. For instance, for an unacclimatised person performing heavy work, the ISO reference value for environmental temperature is about 20ºC (in WBGT).

Recent research into occupational heat stress has shown that workers display a wide variety of body core temperatures, heart rates and sweat production rates – not only between different individuals, but also in the same person, as a result of circadian rhythms and acclimatisation. Moreover, amongst fit workers body core temperatures of over 38ºC have been measured in the absence of objective symptoms of heat illnesses.[29,58] In workplace situations, dose-response relationships between heat stress (in ºC WBGT) and physiological parameters were hardly visible. Researchers have sought to explain the absence of these relationships by reference to behavioural adaptations amongst workers acting to limit their own heat stress as far as possible. The Committee notes that high-quality, large-scale epidemiological studies of subjects in workplace situations have yet to be carried out.

5.2 New scientific insights

The results of more recent scientific research have shown that heat stress also impairs mental performance. Of the mental functions studied, vigilance appears to be the most susceptible to heat stress. A reduction in vigilance has been observed at temperatures above 27ºC WBGT, while the number of unsafe acts increased at temperatures above 23ºC WBGT. Changes in mental performance also appeared sooner than did physical effects.

The existing OELs take no account of the adverse short-term effects of heat stress on mental performance, although there are indications that the NIOSH's recommended OELs for light work may offer protection against these effects below temperatures of 28ºC WBGT.[38]

In the Committee's view, the automation of many work processes and the shift from physically demanding to mentally demanding work has increased the importance of the adverse short-term mental effects of heat stress. Reduced vigilance can threaten the safety of the individual worker and of others.

5.3 Workers running an increased risk

Those who run an increased risk include people with disorders of the heart, the circulatory system, or the thyroid, and diabetics. These groups are more susceptible to heat stress, as are unacclimatised people, older workers, those who take medicines such as diuretics, beta-blockers, antihistamines or psychiatric medications, workers who use alcohol or drugs, pregnant women, and workers who observe a fasting period, for instance for religious reasons.[17,18,27,61,62]

5.4 Conclusions in relation to health-based and safety-based OELs

Reference values for the adverse short-term physical effects of heat stress do not need to be revised

The Working Conditions Act and its regulations comprise, as part of a Policy Guideline, a series of reference values for occupational heat stress taken from ISO 7243:1989 (Table 1). These reference values have no legal status. Both the reference values and the OELs recommended by the NIOSH are founded in health science and based on the prevention of adverse short-term physical effects of heat stress. The Committee is of the opinion that at the present time there are no new scientific insights concerning the adverse short-term physical effects of heat stress that would justify revising existing health-based OELs.

Reference values do not take adverse short-term mental effects into account

The reasoning which underpins the ISO reference values and the health-based OELs recommended by NIOSH takes no account of the adverse short-term effects of heat stress on mental performance. The Committee takes the view that current scientific insights appear to offer opportunities for the establishment of concrete safety-based OELs with regard to the effects of heat stress. The Committee has come to this conclusion on the basis of three findings: 1) adverse short-term mental effects constitute a risk for a person’s own safety and that of others, 2) adverse mental effects have been observed at WBGT values lower than those at which physical effects appear; and 3) there appears to be a dose-response relationship with the environmental temperature. The Committee puts forward no proposals for the level of these safety-based OELs, since this falls outside the scope of the report request.

There is insufficient data about the long-term effects of heat stress

Too few studies have been conducted on the adverse long-term physical and mental effects of heat stress. The Committee takes the view that current scientific knowledge on long-term effects is not an adequate basis for health-based or safety-based OELs.

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Annex **A**

Request for advice

In a letter dated 10 July 2007, reference number ARBO/A&V/2007/22676, the Minister of Social Affairs and Employment wrote to the President of the Health Council of the Netherlands:

On 26 September 2006, during deliberation in the Dutch House of Representatives of a bill to modify the Working Conditions Act, a motion by House members Koopmans and Stuurman was adopted.* This motion requests the government to promptly set up a work programme yielding health-based and safety-based occupational exposure limits (regulations comprising concrete figures), on which advice is to be requested of the government's social partners.

In the debate in the Dutch House of Representatives the former State Secretary for Social Affairs and Employment indicated, in reference to this motion, that it was not the government's intention to include an unbridled number of scientific occupational exposure limits for every conceivable work risk in the Working Conditions Act. This would undermine the essential nature of the Act and run counter to the government's active policy of stimulating customisation in enterprises and sectors, reducing regulatory overhead, and slimming down Dutch supplements to European legislation on working conditions. During the debate the motion's proposers confirmed that it was not their intention that the motion lead to an unbridled number of new concrete regulations in the legislation and regulation, but that the motion would help to support, facilitate and curtail that which the government specified in a working programme.

* Kamerstuk 2005/06, 30 552, no.27. (in Dutch)

In a letter of 18 January 2007 to the Dutch House of Representatives* on the status of the Working Conditions Act, a proposal was made for the further elaboration of the motion. During its General Consultations of 7 February 2007 the Dutch House of Representatives made no remarks on this elaboration, but it did indicate that it wished to be informed on the different phases sketched therein:

- a committee shall be established within an independent scientific institute, which can survey the scientific domain of working conditions;
- this committee shall provide periodic reports of any new (international) scientific insights into concrete health-based or safety-based occupational exposure limits;
- on the basis of the results of these reports the Ministry of Social Affairs and Employment can initiate, where appropriate, further scientific research into health-based and / or safety-based occupational exposure limits;
- the Ministry of Social Affairs and Employment will then assess the need for and desirability of including an occupational exposure limit (as a concrete regulatory paragraph) in the Working Conditions Act and associated regulations. The department will hereby observe the provisions given in the Explanatory Memorandum on the Working Conditions Act, which stipulate that scientific occupational exposure limits will be included in the legislation and regulation if these are generally recognised, have broad social support, and are generally applicable;
- the Ministry of Social Affairs and Employment will then present its opinion on the inclusion or otherwise of an occupational exposure limit in the Working Conditions Act and associated regulations to the Social and Economic Council of the Netherlands (SER) for advice;
- on the basis of the advice put forward by the SER, a decision will be taken on whether to actually adopt the occupational exposure limit in the Working Conditions Act and its associated regulations.

In accordance with the stipulations of the motion, consultations have been held with the government's social partners. It is important that the evaluation of the revision of the Working Conditions Act can be sent to the Dutch House of Representatives within five years of the coming into force of the amendment of the law – that is to say, before 1 January 2012. This evaluation must comprise a report on the practical effects and efficacy of the Working Conditions Act.

On 21 February 2007 we consulted on the possibility of the Health Council establishing a committee comprising experts on working conditions, health, safety, and occupational disease, and the Health Council indicated its willingness to establish such a committee. I therefore request that you establish a committee for the purposes of surveying the scientific domain of working conditions and examining the following subjects:

1 periodic reports on whether *at this moment* new (international) scientific insights exist with regard to concrete health-based and / or safety-based occupational exposure limits;

* Kamerstuk 2006-2007, 25 883, no. 1000. (in Dutch)

2 periodic reports on whether *in due course* new (international) scientific insights may be expected with regard to concrete health-based and / or safety-based occupational exposure limits.

The focus shall be on the first part, periodic reports of current new (international) scientific insights into concrete health-based and / or safety-based occupational exposure limits. In the first instance, these reports will be based on those working condition risks included in the Working Conditions Act and its associated regulations. Other risks may be taken into consideration at a later date.

Please initiate the establishment of the committee and a Plan of Approach for the period 2007 to 2012, which should include reference to all the subjects mentioned above and comprise a budget. I should like to receive the Plan of Approach before next 1 September. The Health Council's Plan of Approach requires the approval of the Ministry of Social Affairs and Employment.

With regard to the periodicity of reporting, I would consider it important to publish an annual report. With this in mind I look forward to receiving the first of these annual reports before the end of 2007.

Yours sincerely,
The Minister of Social Affairs and Employment,
(signed)
J.P.H. Donner

Annex **B**

The Committee

- Professor T. Smid, *chairman*
  Endowed Professor of Working Conditions, VU Medical Center, Amsterdam and working conditions advisor, KLM Health Services, Schiphol-East
- Professor A.J. van der Beek
  Professor of Epidemiology of work and health, EMGO Institute, VU Medical Center, Amsterdam
- Dr. A. Burdorf
  University Associate Professor of Occupational Health, Erasmus Medical Center, Rotterdam
- Professor M.H.W. Frings-Dresen
  Professor of Occupational Health, Coronel Institute for Work and Health, Academic Medical Center, Amsterdam
- Professor D.J.J. Heederik
  Professor of Health Risk Analysis, Institute for Risk Assessment Sciences, Utrecht
- Professor J.J.L. van der Klink
  Professor of Social Medicine, Work and Health, Academic Medical Center, Groningen
- Professor W.R.F. Notten
  Professor of Knowledge Management and Innovation in Healthcare, Erasmus Medical Center, Rotterdam

- R.M. Roodenburg, advisor
  Ministry of Social Affairs and Employment, Den Haag
- Dr. T. Spee
  Occupational Hygiene policy advisor, the Arbouw Foundation, Amsterdam
- J. van der Wal
  Head of Safety, Shell Europa Exploration and Production, Nederlandse Aardolie Maatschappij (NAM), Assen
- Dr. C.A. Bouwman*, scientific secretary*
  Health Council, the Hague
- Dr. A.S.A.M. van der Burght, *scientific secretary*
  Health Council, the Hague

The Committee consulted Professor H.A.M. Daanen, Professor of Thermo-physiology at VU University in Amsterdam and also Head of the Human Performance Department at TNO Technical Human Biology at Soesterberg, as an external expert.

The Health Council and interests

Members of Health Council Committees are appointed in a personal capacity because of their special expertise in the matters to be addressed. Nonetheless, it is precisely because of this expertise that they may also have interests. This in itself does not necessarily present an obstacle for membership of a Health Council Committee. Transparency regarding possible conflicts of interest is nonetheless important, both for the chairperson and members of a Committee and for the President of the Health Council. On being invited to join a Committee, members are asked to submit a form detailing the functions they hold and any other material and immaterial interests which could be relevant for the Committee's work. It is the responsibility of the President of the Health Council to assess whether the interests indicated constitute grounds for non-appointment. An advisorship will then sometimes make it possible to exploit the expertise of the specialist involved. During the inaugural meeting the declarations issued are discussed, so that all members of the Committee are aware of each other's possible interests.

Annex **C**

Comments on the public review draft

In September 2008 the President of the Health Council published a draft of this report and invited a round of comments. The following persons and organisations submitted their reactions to the draft report:

- W. van Veelen, *FNV* Trade Union Federation, Amsterdam
- J. Warning, *FNV Bondgenoten*, Utrecht
- Mrs J. Waage, *FNV Bouw*, Woerden

The Committee considered this commentary in finalizing its report.

Annex **D**

Physiological effects in work situations

Table 3 Acute physiological effects of occupational exposure to heat due to climatologic conditions

Industry or occupational group	Population description	Exposure	Effects	Remarks	Ref.
Building trade (Japan)	12 men (aged 38.1 ± 13.1y)	Varied from 23°C tot 34°C WBGT over the course of the day	Two men had significantly raised blood pressure during work; one man's heart rate was above 110 bpm; two men showed raised osmotic pressure in serum; no differences in serum electrolytes Na, K, Cl and BUN	Measurements for two of the subjects are absent.	Morioka et al, 2006[66]
Various outdoor occupations (Australia)	29 men (aged 18 to 50y)	Summer: 30-35°C; winter: 15-20°C Measurements carried out in a climate chamber at 35°C (29.3°C WBGT) and 50% humidity	Sweat loss: summer 7.8 mL/min, winter 6.9 mL/min Sodium concentration in sweat: summer 44.7 mmol/L, winter 63.8 mmol/L Sodium loss per summer day: 4.8 to 6g.	Sweat loss varied between subjects, from 0.1 to 1.0 L per hour. No correlation between sweat production and body type, fitness or age.	Bates & Miller, 2006[67]

Table 4 Acute physiological effects of exposure to heat-generating sources in the workplace

Industry or occupational group	Population description	Exposure	Effects	Remarks	Ref.
Steel factory (Taiwan)	26 high-exposure (electrical arc smelting) and 29 low-exposure (metal-pouring) male workers. Age: high-exposure 41.6 ± 7.4y, low-exposure 34.9 ± 6.4y	Two days of measurements. High-exposure: WBGT 30.0 – 33.2°C; low-exposure: WBGT 25.4 – 28.7°C	Heart rate: both groups averaged 73-74 bpm at the start of the workday and 77-78 at the end. Blood pressure: in mm Hg Systole High-exposure: start of workday 129.1 ± 11.4 end of workday 126.1 ± 12.1 Low-exposure: start of workday 132.5 ± 11.4 end of workday 130.6 ± 11.2 Diastole High-exposure: start of workday 83.0 ± 9.6 end of workday 82.7 ± 7.5 Low-exposure: start of workday 84.2 ± 9.4 end of workday 85.3 ± 9.8 Body core temperature continuously measured in one person. High-exposure: 36.95 ± 0.23 min-max 36.5 - 37.4°C Low-exposure: 37.14 ± 0.31; min-max 36.5 - 37.8°C	High-exposure workers reported more subjective symptoms of heat stress	Chen et al, 2003[28]
Aluminium smelting plant (Indiana, US)	31 men working around smelting pots; their age is not reported	Over a period of 4 weeks in July and August; 12-hour shifts; average daytime temperature 27.2 ± 0.2°C, max 39°C	Body temperature measured orally: a single measurement > 38°C, 95% < 38.1°C Heart rate: 6-hour average < 110 bpm, 95th percentile approx. 125 bpm; 12-hour average approx. 100 bpm, 95th perc approx. 112 bpm; recovery (after 1 min) average 125 bpm, 95th perc > 160 bpm for several parts of the work process.	Greatest heat load during placing of anodes. No dose-response relationship between T_{oral} and WBGT °C (difference with regard to TLV). Dose-response trend (p = 0.07) between recovery heart rate and WBGT.	Logan & Bernard, 1999[63]
Mining (Australia)	36 male mine workers (aged 35.4 ± 7.6y), 6 male mine workers with office jobs as control (age not reported)	Average WBGT over two summers approx. 31°C (26 - 37); ≥ 10-hour shifts	Average maximum body core temperature: mine workers 38.3°C (SD 0.4); control 37.6°C (SD 0.3). Max. temperature rise per shift: 1.4°C (SD 0.5). Max. heat storage: 431kJ (SD 163)	Circadian variation in body core temperature 0.9°C (SD 0.2). Over a 30-year period, no instances of heat illnesses documented.	Brake & Bates, 2002[29]

Mining (Germany)	38 male mine workers (aged 34.3 ± 5.8y)	Average WBGT 29.1°C (20.5 – 33.7); 125 shifts	Average body core temperature 37.7°C (SD 0.4). Average heart rate 102.8 bpm (SD 23.9), for 92 of 125 shifts; average > 150 bpm. Average sweat loss per shift 3436g (SD 1240)	Dose-response relationship between sweat loss and WBGT. No relationship with body core temperature and heart rate.	Kalkowsky & Kampmann, 2006[58]
Glass production plant (Bulgaria)	16 exposed men (aged 35.9 ± 11.3y), 16 controls (39.5 ± 11.5y); all working in the same department with an average workload	Summer months; exposed to an average WBGT of 36.9°C (29.3 – 41.7); control with an average WBGT of 31.4°C (29.0 – 32.7)	Average heart rate: exposed approx. 100 bpm, control approx. 85 bpm. Hormone concentrations (cortisol, adrenalin and noradrenalin) in urine were significantly higher in exposed group.	Study structure and results are described only summarily.	Vangelova *et al,* 2002[64]
Lifting work while standing vs. typing work while seated	7 women doing seated typing work (aged 20.7 ± 1.9y), 7 women doing lifting work while standing (aged 20.9 ±1.4y)	Measurements carried out in a climate chamber, warm-moist: 30.2°C WBGT and humidity 74%, neutral: 17.7°C WBGT and humidity 50%. Eight periods of 15 min work	Lifting work: Heart rate in warm climate: 119.8 bpm (SD 20.5); neutral: 94.5 bpm (SD 15.8) Body core temperature in warm climate: 38.0°C (SD 0.3°C); neutral 37.6°C (SD 0.3) Skin temperature in warm climate: 35.2°C (SD 0.5); neutral 31.2°C (SD 0.6) Sweat loss in warm climate: 620g (SD 99.2); neutral 160g (SD 72.1) Typing work: Heart rate in warm climate: 90.9 bpm (SD 17.1); neutral 73.1 bpm (SD 11.7) Body core temperature in warm climate: 37.7°C (SD 0.2); neutral: 37.2°C (SD 0.3) Skin temperature in warm climate: 35.5°C (SD 0.03); neutral: 28.6°C (SD 1.0) Sweat loss in warm climate: 262.9g (SD 69.5); neutral 148.6g (SD 67.4) Muscle fatigue (EMG): Lifting work: no significant differences between warm and neutral climate. Typing work: significantly more fatigue in warm climate.		Chad & Brown, 1995[65]

Annex **E**

List of abbreviations

Organisation

ACGIH	American Conference of Governmental Industrial Hygienists
ISO	International Organization for Standardization
NIOSH	National Institute for Occupational Safety and Health
WHO	World Health Organization

Other

bpm	beats per minute
BUN	blood urea nitrogen
CET	corrected effective temperature
CI	confidence interval
EMG	electromyogram
ET	effective temperature
FTE	full time equivalent
g	gram
L	litre
M	metabolism
mmol	millimol
OEL	occupational exposure limit

OR	odds ratio
RAL	Recommended Alert Limit
REL	Recommended Effect Limit
SD	standard deviation
T	temperature
TLV	Threshold Limit Value
W	Watt
WBGT	wet bulb globe temperature
y	year